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THE RICARDIAN MODEL: THEORETICAL AND EMPIRICAL REVIEW

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ABSTRACT

The Ricardian Model is the most widely explained theory in International Economics. Despite its pedagogical importance in this field, its empirical performance is not exempted from controversies. According to this classical model, relative productivities across countries determine trade patterns. On this article, in the model's 200th anniversary, the classical theory is presented along with some extensions and a model where its empirical performance is analyzed. In this model relative productivity and unit labor costs are analyzed as drivers of German and French trade patterns. The results show that coefficients seem to be correctly signed and are statistically significant, even though much of the trade patterns remain to be unexplained. Therefore, other models are necessary to fully explain trade patterns between Germany and France.

KEY WORDS

Comparative advantage, Opportunity cost, Productivity, Unit labor requirements, Unit labor cost

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1. INTRODUCTION

Along the last two centuries, International Trade has been a wide field on Economics due to its importance for the development of countries and in world wealth. On this field, the Ricardian model is considered the first complete theory to be developed. In 1817, David Ricardo published the theory of comparative advantage, which according to Paul Samuelson is one of the very few propositions on Social Science that is true and non-trivial. Along this article this model is explained jointly with some extensions and, it is also tested empirically.

At the beginning of the 19th century, Ricardo lived the industrial revolution on his country, realizing that English income was growing. He looked for reasons, since it was difficult to find a key factor that leads those income increases. There were many changes: more hours worked, introduction of new energy sources, new technologies were developed, production increased... The Ricardo's aim was finding the key element and he wondered if trade was the cornerstone of wealth creation. So he developed the model for stating what drives this increase in trade.

Two centuries have past since the theory was born. At first it was revolutionary, then empirically studied by different researchers and then different economists have tried to improve it theoretically, by making more realistic assumptions. Afterwards new theories about international trade have been developed, but the vast majority of them are based on the idea of comparative advantage. It is the baseline for more modern theories, as Heckscher-Ohlin theory (which includes more factors of production), the different models that explain economies of scale... For this reason, Ricardian theory is explained on every international trade course and textbook, usually on the first chapters.

The aim of this paper is to prove (or not) the theory empirically, and if it continues to explain trade drivers 200 years after, with an economic and social framework radically different from the existing in 1817. Theoretically it is irrefutable, and for this reason after two hundred years is currently explored, tested, improved... instead of left apart due to obsolescence.

Last years, attention has come back to this theory due to the extensions that have been added to it, making it more useful and easier to handle. Even though there exists more modern empirical studies, on this paper the analysis is based on a test made on Balassa (1989), for its intuitive comprehension and logic.

This research is structured as follows: in section 2, the base model (comparative advantage concept and the theory as a whole) is presented; section 3 explains the reasons why it is interesting to develop an empirical study on the Ricardian theory (as well as the strengths and weaknesses of the empirical representation of the model). Finally, in section 4 the variables that will be used are presented, and section 5 contains the developed empirical model. Finally, on section 6 the conclusions obtained are presented.

2. THE RICARDIAN MODEL

In 1817, David Ricardo introduced the concept from which is built the whole model: the comparative advantage. Based on it, the model was developed and presented for the first time by Mill (1844) according to Ruffin (2002).

From then on, other authors have extended the theory, adding complexity to it in order to make it closer to reality and to the modern world.

2.1 The concept of Comparative Advantage

This concept presented on Ricardo (1817) was revolutionary, against the one assumed until that moment, the concept of Absolute Advantage, stated by Adam Smith (1776). The last one stated that if one country has absolute advantage over a trading partner on one or more industries, so to say, it has a higher productivity (can produce more with the same inputs) he should export goods produced by this industries.

On the other hand, the Ricardian comparative advantage concept relies on the opportunity cost. Instead of focusing just on absolute productivity, it relies on the trade-off between using the given resources of the country in producing one good or the other.

The following example is presented to facilitate the understanding of this idea. Table 2-1 contains information on the productivity of two countries (A and B) for producing two goods (X and Y).

Table 2-1. Production output per hour of work

		Goods	
		X	Y
Countries	A	1	10
	B	1	5

Source: Own elaboration

Country A can produce 1 unit of X with devoting 1 hour to this good, while it could have produce 10 units of Y devoting this same hour to produce good Y, so the opportunity cost of one unit of X are ten units of Y. If on country B the opportunity cost of one unit of X are five units of Y, country B has to give up less units of Y (5) to produce the same amount of X. In this case, it is said that country B has a comparative advantage on X, meaning that country A has a comparative advantage on Y (giving up the same production of X can produce more units of Y).

Stating this idea, one country has comparative advantage in one good if the opportunity cost of this good (in terms of others) is lower on it that on the other countries. This implies that the opportunity cost of the other goods will be higher on it than in others.

This can make intuitive the idea that countries can use their resources producing the good in which they are more productive in relative terms and then trade, which lead both countries to gain from it.

2.2 The model

The Ricardian model was built for two countries, Home and Foreign, each of them producing two goods, X and Y, only with one factor, labor (L). An extensive explanation of the model can be found in Krugman, Obstfeld, and Melitz (2014), from which it derives the presentation of the model made here.

2.2.1 The assumptions

Labor supply is given and equal to L and L^* ¹ being perfectly mobile across sectors but immobile across countries. The use of this labor in production has constant returns to scale, so independently of the quantity produced, the same amount of labor is needed for producing one unit. This fixed amount of labor is called unit labor requirement and denoted as a_i and a_i^* for each good $i=X,Y$. Markets are assumed to be perfectly competitive, which implies that price equal cost of production so for wages w : $p_i = w_i a_i$ and so $p_i^* = w_i^* a_i^*$.

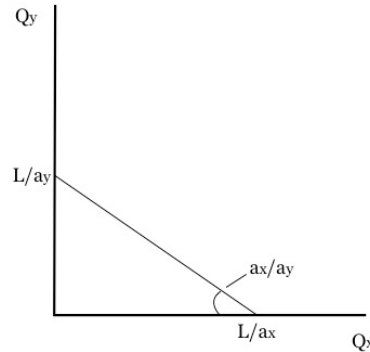
2.2.2 The autarkic equilibrium

In autarky, both goods have to be produced on each country in order to be consumed. To know the quantities produced (and thus consumed) further knowledge about the

¹ Superscript * is used all along the text to refer to Foreign variables.

indifference curves of each country is needed. What it can be said is that relative prices ($p = \frac{p_x}{p_y}$)² are going to equal relative unit labor requirements or the opportunity cost of X in terms of Y (a_x/a_y); this is because as labor is perfectly mobile across sectors, wages on both sectors on each country must be the same since otherwise all the workers will want to work on the highest-wage-paying sector, increasing the labor supply and thus decreasing.

Figure 2-1. Home's PPF



Source: Own elaboration

If trade does not occur, the production and consumption of the country is limited by the available labor: $a_x Q_x + a_y Q_y = L$. This is called the production possibility frontier (PPF) and it is shown on Figure 2-1.

It is known that in autarky, Home will produce and consume a combination of both goods that is in the PPF, and the exact one will be chosen maximizing the utility function. It may be expected that Foreign production also is constrained by his PPF. But this one, will have a different slope equal to $\frac{a_x^*}{a_y^*}$. From then on, it will be assumed that $\frac{a_x}{a_y} < \frac{a_x^*}{a_y^*}$, so to say, the opportunity cost of good X in terms of good Y is smaller in Home than on Foreign. It can be said that Home has a comparative advantage on good X while foreign has it on good Y.

2.2.3 World's relative price under free trade

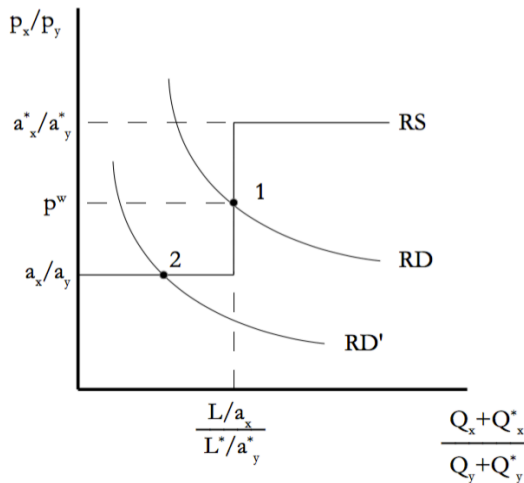
As it is stated before, relative prices on autarky equal relative unit labor requirements, so $\frac{p_x}{p_y} = p < p^* = \frac{p_x^*}{p_y^*}$. This imply that if those two countries open their frontiers to trade,

² Along the text, relative prices are represented as p , but it is important to remember that always make reference to $p = \frac{p_x}{p_y}$.

assuming free trade and no transport costs, relative prices will change and become equal as the two countries become just with respect to trade.

This unique relative world price (p^w) will be determined by the world's relative supply and world's relative demand and it will be analyzed on a general equilibrium analysis for taking into account the relation between both market of good X and Y.

Figure 2-2. World Relative Supply and demand



Source: Own elaboration

In this graph it can be seen that relative demand (RD) is downward sloping representing that when the relative price of X in terms on Y decreases, the relative demand of X in terms on Y increases.

By contrast, it can be seen that the relative supply function (RS) does not look like a upward sloping curve, but it has different segments. On the following lines it is going to be

explained each of these segments. The

first one, when $p^w < \frac{a_x}{a_y}$, relative supply is 0 (represented by the vertical segment from the origin to the point $(0, \frac{a_x}{a_y})$ so there will not be supply of X, since if $\frac{p_x}{p_y} = \frac{w a_x}{w a_y}$ and $\frac{p_x}{p_y} < \frac{a_x}{a_y}$ it implies that the difference must be on the salary, so there is no one willing to work producing good X for an smaller salary, if he can earn more producing Y. As it is previously stated that $\frac{a_x}{a_y} < \frac{a_x^*}{a_y^*}$, the same happens on foreign (salaries are also smaller for people working for industry producing good X than for good Y).

The first flat section happens when $p^w = \frac{a_x}{a_y}$, at that point, Home workers are indifferent between working producing X or Y since on both sectors they earn the same wage so when this happens, Home produce both goods, and the exact quantity of each of them is defined by the RD. On this flat section, Foreign workers continue to be specialised on good Y for the same reason as before.

The next segment is the vertical line, that takes place when $\frac{a_x}{a_y} < p^w < \frac{a_x^*}{a_y^*}$. When world's relative price is strictly higher than Home's opportunity cost of X, all the workers

want to work on it since they earn a higher salary than if they work on Y, so Home is fully specialized on the production of X. Meanwhile, Foreign continues to be fully specialized on good Y so all its labor force will be employed on its production. It is possible to know that as long as the world relative price is in between each country autarkic price, both countries will be fully specialized on the good in which they have a comparative advantage so the world relative supply will be: $\frac{L/a_x}{L^*/a_y^*}$.

When world relative price equals Foreign's opportunity cost of X, Foreign workers will be indifferent between working on each of the sectors while Home workers will continue to be fully specialized.

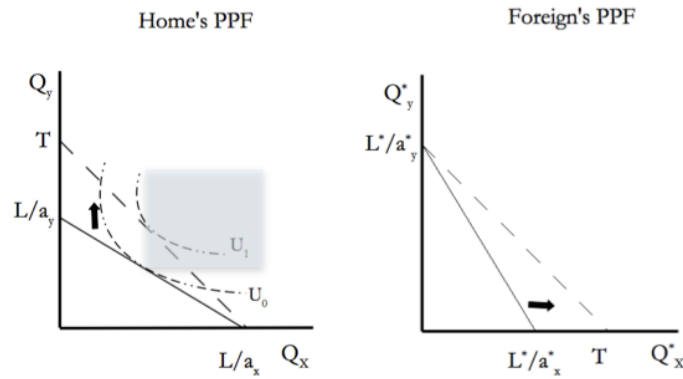
Finally, if world relative price become greater than that, both countries will only produce good X and thus no good Y will be produced, so the relative supply of X will be infinite.

The world price is determined by the intersection of RD and RS as well as the relative quantity produced and consumed of each good so as on the examples in Figure 2-2.

2.2.4 *The gains from trade*

From hereafter, it will be assumed that once trade happens, both countries will be fully specialized, and also will be assumed that if two countries trade between them is because they gain from it. How can be proved that both trade and specialization are beneficial? Trade allows countries to consume a combination of goods different from the one they produce, so as can be seen on Figure 2-3, the PPF continue to be the same as before trading (the continuous line) but when they trade, they expand their consumption possibilities (discontinuous line). This line is a budgetary restriction with a negative slope, equal to the world's relative price. In both countries, after trading, people can reach higher indifference curves by choosing different mixes than before; each point of the PPF can be now substituted by another from the discontinuous line having more of both goods (Shown on Figure 2-3, Home's diagram). Trade enlarges the consumption possibilities of the country making people better off.

Figure 2-3. Expansion of the consumption possibilities



Source: Own elaboration

2.2.5 The importance of relative wages

Until this moment, nothing has been said about relative wages but it is known that there exist big differences between the wages of countries that trade. People are concerned with this issue since some believe that trade can make poorer the workers of countries with low wages. As it has been stated, prices equal the cost of producing the goods, so relative wages have to be in between the relative productivities in order to give each country a cost advantage on each good. It can be seen that if on Home is needed 3 times the amount of labor needed in Foreign to produce good Y, but their wages are 1/5 of the Foreign's one, it is cheaper to produce it at Home even though it takes more labor. So for Home to have a cost advantage on good X and Foreign on good Y both of the following inequalities must be fulfilled: $wa_x < w^*a_x^*$ and $wa_y > w^*a_y^*$.

So it is important to know that relative wage must be in between relative productivities of good X and of good Y, so to say, $\frac{a_x}{a_x^*} < \frac{w^*}{w} < \frac{a_y}{a_y^*}$.

2.3 Extensions of the Simple Ricardian Model

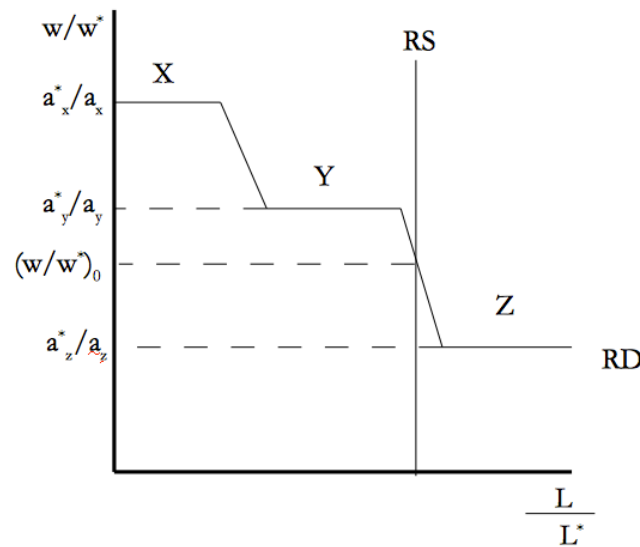
As said before, through the years extensions to this model have been added in order to make it closer to reality and looking for a better fit with new world situation (for example, globalization). The most important extension has been adding more than two goods to the model. On the following pages, two of those extensions comprising the addition of more goods to the model are presented.

2.3.1 More than two goods

Adding more goods is straightforward once the idea of cost advantage has been understood. Good Z will now be introduced. Its unit labor requirements are a_z at Home and a_z^* at Foreign. Goods will be ordered by relative Home's productivity advantage, on the form of a chain of comparative advantage: $\frac{a_z^*}{a_z} < \frac{a_y^*}{a_y} < \frac{a_x^*}{a_x}$.

On this situation, which goods are produced in each country depend on the relative wage rate, that means that goods will be produced on the country where it is cheaper to do it so. For that w/w^* must be located on the chain, “breaking” it. Goods that end up at the left of the cut are cheaper to produce at Foreign while the ones located at the right are produced at Home. Now the important question is what determines the relative wage that breaks this chain. It is determined by the labor demand and supply of one of the countries relative to the world as it is shown on Figure 2-4.

Figure 2-4. Wage determination in the Many Good Model



Source: Own elaboration

On this figure, the downward sloping curve is the relative demand (RD) for Home labor while the vertical line represents the relative supply (RS) for Home labor. This vertical line represents the given Home labor supply relative to the given relative Foreign labor. It is vertical since it is completely inelastic, so it is assumed that the labor force is fixed, and all the workers will work independently of the relative wage paid (since labor is assumed to be immobile across countries).

A more detailed explanation is needed in order to understand the RD curve. Firstly, the labor demand is zero when $\frac{w}{w^*} > \frac{a_x^*}{a_x}$ because Home has not any cost advantage, so as all the goods are more expensive when produced at Home. There is no demand for Home workers since nothing is produced at Home. This changes when $\frac{w}{w^*}$ becomes equal to $\frac{a_x^*}{a_x}$. Since Home has its higher relative productivity on good X, at that moment, Home starts being competitive at its production. Now $wa_x = w^*a_x^*$, so people are completely indifferent between buying good X from Home or Foreign, so labor demand is completely elastic from 0 to the end of the horizontal segment which represents the point at which the demand for good X is saturated at price wa_x , so no more workers are needed at Home.

When relative wages decrease, it becomes cheaper to produce good X at Home, so Home becomes the only producer of good X, needing more workers to increase the production and fulfill the world demand of good X.

Then, if $\frac{w}{w^*}$ become equal to $\frac{a_y^*}{a_y}$, Home becomes also competitive on the production of good Y with a completely elastic labor demand until the saturation of the market at that price, and so on.

So it can be seen that at the intersection of RD and RS on Figure 2-4, the relative wage is defined. It equals $(\frac{w}{w^*})_0$ and it falls in between the relative productivity of good Y and good Z, so the comparative advantage chain will be: $\frac{a_z^*}{a_z} < (\frac{w}{w^*})_0 < \frac{a_y^*}{a_y} < \frac{a_x^*}{a_x}$, being goods X and Y produced exclusively at Home, while good Z is exclusively produce at Foreign.

This model implies that the countries with larger relative workforces must have lower relative wages in order to achieve full employment.

Finally, it is important to highlight that Home goods demand can increase on two different ways due to a decrease on relative wages: a greater quantity of the goods that are already being produced at Home can be demanded or by contrast, a greater variety of products produced at home can be demanded. These two kinds of demand growth are called by Eaton and Kortum (2012) growth at an intensive margin and at an extensive margin respectively.

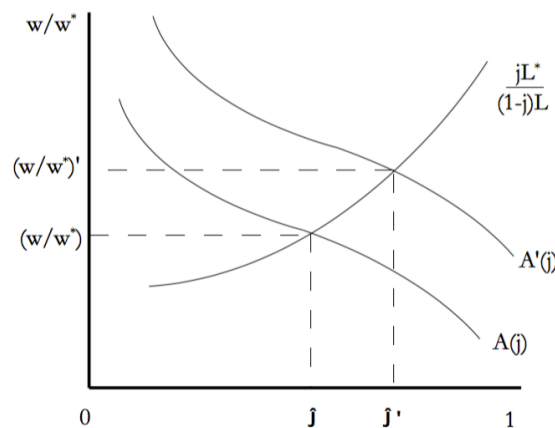
2.3.2 More goods than you can count

The problem with the former extension was the fact that not only some goods are traded. Nowadays many of the goods produced by countries are traded, this does not hold for services since they are less traded. When thousands of goods are traded, a graph with a stair shape as the one presented in Figure 2-4 is tedious for solving for the equilibrium as well as to use it on comparative statistics.

For this reason, Dornbusch, Fischer and Samuelson (1977) transformed this stairway on a ramp. By adding thousand of new goods to the stair, each step becomes smaller, until the point in which the difference between each good's three possible outcomes (produced at Home, at Foreign or on both) becomes insignificant.

On that paper, all the set of goods are assumed to correspond to all the points on an interval between 0 and 1, arranging them on the form of a chain of comparative advantage (where Home has the strongest comparative advantage in goods closest to zero while Foreign does it so on the ones nearest to 1. Then a function is defined ($A(j)$) as the relative Home productivity advantage for each j between 0 and 1, so to say, the ratio of Foreign unit labor requirements to Home's ones. This function is assumed to be smooth and downward sloping. This function is represented on Figure 2-5.

Figure 2-5. Wage determination with a Continuum of Goods



Source: Own elaboration

For any relative wage $(\frac{w}{w^*})$ between $A(0)$ and $A(1)$ there is a good which is going to be called \hat{j} such that $A(\hat{j}) = \frac{w}{w^*}$. This good is the cutting point in the comparative advantage chain and it is equally costly to produce at Home or at Foreign and who produces it is irrelevant since it is an infinitesimal fraction of the total set of goods. Home

will produce goods such that $j \leq \hat{j}$ (on the graph located at the left of the cut) while Foreign the ones which $j \geq \hat{j}$ (at the right). As j goes from 0 to 1, \hat{j} also equals the share of goods produced at home, either to be consumed there or at Foreign. Due to the negative slope of this function, a decrease on Home's relative wage, increase the share of goods produced at Home.

As before, to know which is the precise relative wage that breaks the chain, the demand side has to be analyzed. A higher \hat{j} means producing a higher share of goods, thus increasing the demand for labor and so the relative wage $\frac{w}{w^*}$ increases. This positive relation is represented on Figure 2-5. On this figure is also represented what happens with a Home increase in productivity ($A'(j)$). For the same relative wage, a larger share of goods is cheaper to be produced at Home so the downward sloping curve shifts, leading to a higher relative wage as well as to a greater Home produced share of goods.

Until this point it has been assumed that Home and Foreign have the same tastes and spend their incomes on the same way (meaning identical, homothetic preferences). But if data is analyzed, it can be seen that this does not occur in reality, each country tends to spend a higher share of their incomes on goods that are nationally produced. As a way to explain it, on Dornbusch et al. (1977) the Samuelson's iceberg assumption, which states that to deliver one unit of a good to another country d units have to be shipped, being $d \geq 1$. This introduces transport cost, representing the fraction of goods that are damaged or broken in the shipment. These transport costs make more expensive some traded goods in which the cost advantage is small. This would happen on good j if $wa_j < w^*a_j^*$ but when introducing d : $wa_jd > w^*a_j^*$, giving birth on the model to the not traded goods (in this case Home lose its cost advantage and each country will consume nationally produced good j). It is assumed that even with this cost, there still are traded goods (the closest to zero shipped from Home and the closest to one from Foreign).

3. STRENGTHS AND WEAKNESSES OF THE RICARDIAN MODEL

The model that will be replicated on this paper is based on Balassa (1989). Before proceeding with the test, it is going to be analyzed why this model should be tested. Its strengths will be presented along with its weaknesses.

3.1 Weakness: Incomplete Specialization

The most problematic feature of the original model is the assumption of specialization of each country on tradable goods. On real life, is not usual to see that industries disappear because of having comparative disadvantage. An example can be made thinking about a tailor. Even if nowadays importing low quality cloths is really cheap and there are big firms selling medium quality-low prices cloths, there still exist tailors that made unique cloths for their clients, that there are willing to pay more for them. Some explanations of this incomplete specialization are presented below (even though literature has presented more).

3.1.1 *Disequilibrium effects*

The disequilibrium interpretation is that the price and quantity equalization between countries is a slow process, so if it is not at its ending point, incomplete specialization can happen. The differences on prices or unit labor costs will tend to disappear under this explanation, but empirical works such as Giovannini (1988) show that deviation from purchasing power parity (PPP) do not tend to disappear along time even on basic goods. This interpretation leads to take as explanatory variable for further studies the relative unit labor costs instead of the relative productivities in order to allow for sectorial wage differences as sources or consequences of sectorial competitiveness.

3.1.2 *Product differentiation*

The product differentiation interpretation as the reason for incomplete specialization implies that comparative advantage can coexist with intraindustry trade. With this interpretation it is possible to reject Bhagwati's (1964) objection to the former test on Ricardo's theory. He argued that if there is not prices equalization between the trading countries, tests should study the relationship between trade flows and prices instead of the unit labor costs. But if product differentiation is allowed, then price equalization, incomplete specialization and productivity differences could be consistent. This consistency is explained on Krugman (1981) based on the Dixit-Stiglitz monopolistic competition model. If country 1 has a comparative advantage on industry A with respect to industry B when comparing with country 2, then country 1 will produce more varieties and become net³ exporter of goods on industry A. The prices of each variety will be equal on both countries, so there is a link between trade flows and comparative advantage, even on intraindustry trade.

³ It is net exporter but not the only exporter as consequence of incomplete specialization.

3.1.3 *Some more reasons*

Some other reasons have been found that justify incomplete specialization. Some of them will be here presented:

- *Transport costs:* If there exist transportation costs, even if one country has a relative comparative advantage in one good, it can lose its cost advantage because of the transportation cost. For example, there is evidence that there is smaller international trade in goods which have high weight-to-value ratios (Krugman, Obstfeld, and Melitz, 2014). This happens because transport costs offset the cost advantage of producing it on a country, which has comparative advantage on it.
- *More factors of production:* Goods are not produced solely with human labor, so when the Ricardian model is studied, the rest of factors such as land, technology... are left apart. So it may happen that even if a country has a comparative advantage, its available technology does not allow its workers to produce enough (so they will need to further import this good).
- *Barriers to trade:* Along history, countries have sought protecting their national production with barriers to trade (as for example with tariffs) and even if nowadays due to different trade agreements, these barriers have been reduced, but they have not fully disappeared. These barriers have a similar effect on trade as transport costs; they distort relative cost advantages of countries. Even if a country has a relative cost advantage on a good, if the tariff is high, can make this good more expensive to buyers on the tariff country, so they won't be willing to buy yours. That way, this good can become non-tradable (each country consumes what it produce).

3.2 **Strengths: Technology and Labor Costs as the source of Comparative Advantage**

The classical model, as it has been seen, takes into account the differences between the unit labor costs as the origin of trade. This can seem to be a very big simplification of reality, which can distort the results, but it is not like that. Instead, there are many advantages on leaving aside factors such as capital and other intermediate inputs.

Firstly, labor is the less tradable input, since nowadays raw materials and financial capital are very mobile inputs this fact decreases its importance on determining the

countries comparative advantage. As Jones (1980) stated, when inputs are very mobile, absolute advantage is much more important than comparative one. This is because the location of these inputs is not given but endogenously determined, so a country comparative advantage cannot be originated by it. Ferguson (1978) demonstrated that even under a standard two-factor model setting, if there is perfect international capital mobility, relative labor productivity is the only source of comparative advantage. In some cases, capital mobility and trade are substitutes if trade results in factor-price equalization but if there are technological differences between countries that are industry specific, factor prices are less likely to be equalized through trade. Although technology (through smaller unit labor requirements) and labor cost are not all the inputs involved, a good insight can be obtained by studying its relation with trade.

Secondly, recently, different studies have identified great differences on levels of labor productivity in different sectors but few of them have tried to relate them with trade flows. These differences imply that technology is not neutral across sectors, which is the baseline of the Ricardian model, assuming that this is the origin of the comparative advantage and furthermore, the origin of international trade.

Thirdly, for practicality, is much easier to obtain labor productivity data than for other costs of production. For this reason, keeping the utility of the studies, they are much easier to conduct.

Finally, as Deardorff (1984) defends, productivity based models (as the Ricardian one) and factor-endowment one (as Heckscher-Ohlin model) are compatible. If great differences on factor endowments give rise to specialization, sectors in which the country is specialized will have higher productivities.

4. DEFINING THE MODEL

So far, the Ricardian Model has been presented. In what follows, we will analyze its empirical performance. The regressions that will be performed are inspired by these in Balassa (1989). In particular, we will study the relation between relative productivities and trade, as well as labor cost and trade. The analysis will be implemented with GRETL, specifically with the panel data models. Two big types of regressions will be estimated. A first one where the independent variable will be relative productivity while on the second it will be relative unit labor cost. For both classes three regressions will be estimated, with three different dependent variables, which will be specified below.

4.1 Data

We have collected from the OECD STAN (Structural Analysis) database, specifically from its third revision. It is based on SNA93 National Accounts and the industries are classified following the International Standard Industrial Classification. The empirical performance of the model will be analyzed for France and Germany. The period of time covered is the widest available on all the variables and both countries: 1991-2007.

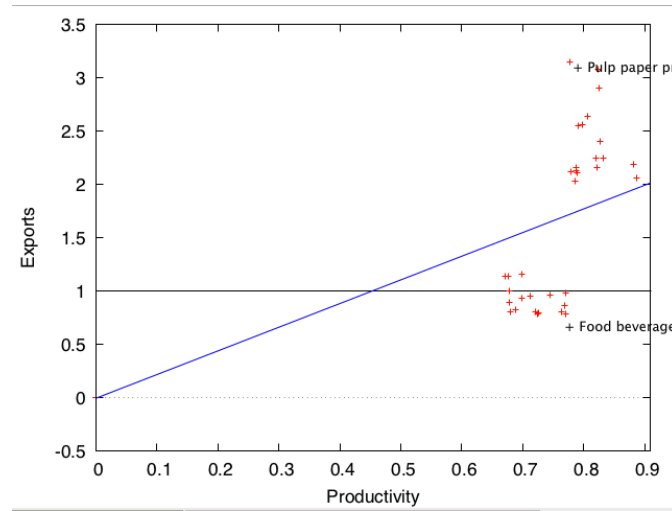
Ten activities of the manufacturing industry have been selected for the study (they are: Food beverages and Tobacco, Textiles leather and footwear, Wood and Cork, Pulp paper printing and publishing, Chemical rubber plastics and fuel, Non-metallic products, Basic metals and fabricated metal products, Machinery and equipment, Transport equipment and Manufacturing n.e.c and Recycling). Thus for each country there exists a panel composed of ten industries and 17 years.

For this reason, it is assumed that the effects on the error term of the regression will be temporal (there is a fixed component of the error that is anchored in time), so to say, it varies between industries but not over time.

A selection of particular industries was needed as data preparation was very costly so, including all the sub-divisions of the ISIC Rev. 3 classification was beyond the scope of the present paper.

An example of how data can reflect trade based on comparative advantage is presented on Figure 4-1. Data from two industries are represented, specifically from Food beverages and Tobacco and Pulp paper printing and publishing. Each point represents one of those industries in one year. It can be seen that on both industries French productivity is higher than German one, since relative production (Germany over France) is smaller than one in all the cases. Exports are presented as a relative measure thus, points over the horizontal line of value one represent years in which a German industry exports have been greater than French ones. Two data groups can be observed. The first one, located mainly below the horizontal line (Food beverages and Tobacco) and the second one above (Pulp paper printing and publishing). Thus, even if France has an absolute productivity advantage on both industries, its opportunity cost may be greater on Food beverages and Tobacco, for this reason and driven by comparative advantage, France is exporting more Food beverages and Tobacco than Germany but less Pulp paper printing and publishing than Germany.

Figure 4-1. Trade based on comparative advantage



Source: Own elaboration

4.2 The variables

On this section the variables used on the regressions as well as how they have been computed are presented.

4.2.1 Unit labor requirement/Productivity

The unit labor requirement for sector i on country j and time t will be denoted as a_{itj} and defined as:

$$a_{itj} = \frac{L_{itj}}{Q_{itj}}. \quad (1)$$

Here L represents labor employed (measured as people engaged on production in each sector) and Q represents the value-added (it has been deflated, having now value added at constant prices with base year 2000 and national currency). This unit labor requirements are assumed to be independent from production; so to say, there are constant returns to scale. As value added is measured on national currency, on the empirical model both are going to be measured (Germany and France) along the whole period in Euros.

4.2.2 Export ratios

Typically, most studies have been developed with considered (relative exports $\frac{E_{itj}}{E_{itj}}$, meaning exports of sector i and country j in year t . Several papers have analyzed trade between UK and US (see e.g. MacDougall (1951), Stern (1962), and Balassa (1963)). The first two used this ratio taking into account total exports while Balassa excluded bilateral

trade between them (as bilateral trade magnitude might be affected by tariffs). Although there are no trade barriers between Germany and France, in this case, the analysis will be carried out with both measures, in order to check if this specific trade affects results⁴.

Total exports of each country are not available on the database, only bilateral exports are presented. For these reason, bilateral exports have been taken (with the whole world) so the result of adding up all of them is total exports. They are also measured on Euros and current prices on the original data and have also being deflated but this time with each country Consumer Price Index (CPI).

4.2.3 *Bilateral exports*

Usually bilateral trade data is more intuitive (and in fact it is used on different papers to assess comparative advantage) since transport costs do not alter the results as they are the same on both directions (it has the same cost to transport goods from France to Germany that the other way round).

As the theory explains, this value is thought to be the most precise trade measure in order to prove the relation between productivity and trade.

4.2.4 *Wages*

Wages are also a useful variable since from them the cost of producing can be computed and not only productivity will be related with relative trade but also with the relative cost advantage. This variable is measured in Euros and it is defined as wage and salaries per employee in each industry per year.

Table 4-1 presents a summary of the data available, per industry as an average of the period of analysis. A panel of the ten industries along the 17 years has been constructed, relativizing the measures of both countries (Germany over France). The corresponding values for France are standardized to 100, so values greater than 100 imply that the corresponding variable on a particular industry is greater in Germany than in France. By contrast, if it is smaller, that variable is greater in France.

⁴ This fact is not expected to alter the results since both of them are part of Europe, so the tariff between them is inexistent.

Table 4-1. Summary of variables

FRANCE =100	Productivity	Exports	Exports Excluding Bilateral Trade	Bilateral Exports	Wage/ employee
Food beverages and tobacco	71,6	88,0	91,7	69,0	94,9
Textiles leather and footwear	96,3	155,0	162,3	111,4	108,4
Wood and cork	102,9	193,8	210,7	125,7	126,2
Pulp paper printing and publishing	81,3	224,8	239,5	162,4	78,5
Chemical rubber plastics and fuel	76,1	174,9	187,1	109,4	104,4
Non-metallic products	96,7	170,0	184,8	102,2	108,9
Basic metals and fabricated metal products	93,9	217,2	243,3	116,4	113,6
Machinery and equipment	107,9	272,4	293,7	158,0	119,1
Transport equipment	103,1	212,7	217,4	188,7	131,7
Manufacturing n.e.c and recycling	95,5	201,9	205,3	184,7	120,0

Source: Own elaboration using OECD STAN data

5. EMPIRICAL PERFORMANCE OF THE MODEL

On this section, several regressions are going to be estimated so we can extract conclusions regarding the empirical performance of the Ricardian model. Firstly exports are going to be regressed against productivity (meaning by exports the three measures previously discussed). After that, relative costs are going to be introduced as regressor.

5.1 Productivity and exports

Firstly, the effect of relative productivity on relative exports is compared. The two variables involved are relative exports and relative productivities defined as $\frac{P_{itG}}{P_{itF}} = \frac{1/a_{itG}}{1/a_{itF}}$, where subscripts G and F denotes Germany and France repeatedly. The summary statistics for the variables that are used on the regressions are presented on table 5-1.

Table 5-1. Summary statistics

	Mean	Median	S.D.	Min	Max
Total Exports	1.911	1.937	0.5429	0.7401	3.393
Exports Excluding Bilateral	2.036	2.031	0.5827	0.7804	3.668
Bilateral Trade	1.328	1.207	0.5037	0.5291	3.609
Productivity	0.9252	0.9340	0.1473	0.6711	1.409

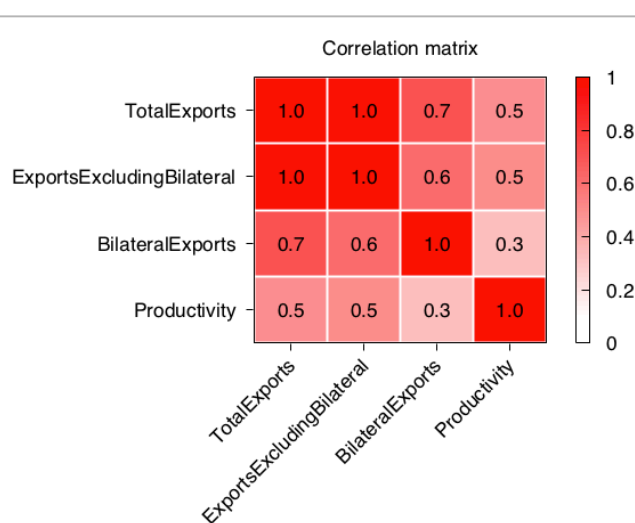
Source: Own elaboration

It can be seen that on average (with the data of the 10 industries and 17 years) Germans exports (when bilateral trade is excluded) double those of France, while the productivity of France is on average higher than that of Germany.

Regarding total exports, the difference between the two countries slightly decreases. For bilateral trade, these differences are further reduced: German exports are now only 30% higher than the French ones.

The correlation matrix of productivity and the three exports variables has been computed in order to measure which correlation is stronger:

Figure 5-1. Correlation Matrix: Productivity vs. Exports



Source: Own elaboration

These correlations coefficients show us the statistical relationship between each pair of variables. By definition, correlation coefficient lay between $(-1, 1)$. If it is negative, it means an inverse relationship (if X increases, Y decreases) and if it is positive, it represents a positive relationship (if X increases, Y increases). To know the strength of the relationship the value (in absolute terms) has to be analyzed being the strongest correlation represented by value 1, while a 0 represents no relationship. The correlation of interest in this case is the one of productivity with the different proxies of trade, so last column contains the information needed. It can be seen that all the variables are positively correlated (if productivity increases, all the measures of exports increase). The strongest correlation is with exports excluding bilateral (the measure originally used by Balassa (1989)) and the weaker correlation is between productivity and bilateral trade.

5.1.1 Exports excluding Bilaterals

Whit the aim of analyzing the relationship between the relative productivity of each country and their relative exports, Balassa's (1989) analysis will be replicated.

The following regression model will be estimated:

$$\frac{X_{itG} - B_{itG}}{X_{itF} - B_{itF}} = \lambda_1 + \beta_1 \frac{P_{itG}}{P_{itF}} + \varepsilon_{it1}, \quad (2)$$

where X_{itk} is total exports, B_{itk} denotes Bilateral exports and finally P_{itk} representing productivity. In all the cases subscript itk refers to industry i in country in year $t = 1991, \dots, 2007$ in country k ($k = G, F$).

A positive relationship is expected since the larger the relative productivity (difference between Germany over France) the higher the German exports are expected to be with respect to French ones (as the positive correlation coefficients anticipated). The model is estimated using fixed effects and random effects methods and the results are the following:

	Fixed Effects	Random Effects
const	0.891302 (0.274537) ***	0.833349 (0.306046) ***
Productivity	1.22434 (0.292853) ***	1.28634 (0.285891) ***

Results are quite similar and under both estimation methods. A Hausman test is constructed, in which the hypothesis is:

H_0 : GLS estimates are consistent

H_1 : H_0 is not true

The estimation method under the assumption of the presence of random effects is named GLS. By definition, the coefficients estimated under fixed effect assumption are consistent, while the ones estimated with GLS method, are by definition efficient. This test is made with the aim of knowing if the estimated coefficients under random effects assumption are efficient as well as consistent. If the null hypothesis is rejected, there is evidence to conclude that on this case, GLS estimates are not consistent, so estimates under the fixed effects method will be chosen. This will happen when the p-value of the test is smaller than 0,05. On this paper we have chosen a significance level of 5%. Otherwise, there is not enough evidence to conclude in favor of the alternative hypothesis.

On this case estimators under random effects method will be used since they appear to be both efficient and consistent.

The test has a p-value = 0.323178, so is not rejected H_0 , which means that the estimation under random effects method will be chosen. Thus the estimated model is:

$$\left(\frac{\widehat{X_{itG}} - B_{itG}}{\widehat{X_{itF}} - B_{itF}} \right) = 0.83 + 1.29 \frac{P_{itG}}{P_{itF}} \quad (3)$$

It can be seen that on the estimated model, the estimated coefficient of productivity $\widehat{\beta}_1$ is significant (which means that there is enough evidence to say that it is different from 0). this can be shown on the table of results represented by the stars. Estimations with only one star are significant at a 10% level, so to say, if the estimation is repeated with another random sample of the same characteristics, 90% of the cases will be different from zero). Two stars means that it is significant at a 5% level. Finally, three stars mean that it is significant at a 1% level.

In this case, as the estimated coefficient is significant even at a 1% level, it can be said that productivity has an effect on the relative exports of Germany and France. Furthermore, it can be said that this effect is positive as it was expected. The larger the relative productivity is (so to say, the larger the gap between German and French productivities), the larger relative exports will become (the larger the gap on exports). If productivities are equal on both countries, Germany will export more than the double than France to third countries. France would need to be 7 times more productive than Germany in order to export the same like Germany.

5.1.2 Total Exports

Next, we change the dependent variable, which is now the ratio of total⁵ exports (Germans over French). Thus, the estimated model is:

$$\frac{X_{itG}}{X_{itF}} = \lambda_1 + \beta_1 \frac{P_{itG}}{P_{itF}} + \varepsilon_{it1} \quad (4)$$

As mentioned above the inclusion or exclusion of the bilateral trade it is not expected to have a big impact on the analysis due to de lack of barriers among the European countries throughout the entire period of study.

⁵ It is important to remember that when about total exports are referred, it has to do with the partner countries (including all of them), not with the whole amount of French or German exports, since only ten industries (not services, not first sector activities as agriculture...) are taken into account.

The next table summarizes the estimations results:

	Fixed Effects	Random Effects
const	0.692813 (0.271883) **	0.645180 (0.29717) **
Productivity	1.30283 (0.290022)***	1.35379 (0.281815) ***

Again, a Hausman test is constructed in order to decide which estimation approach is chosen, even if irrespective of the estimation method used, the results are very similar:

Hausman test -

Null hypothesis: GLS estimates are consistent

Asymptotic test statistic: Chi-square (1) = 0.588314

with p-value = 0.443072

As the test has a p-value greater than 0,05, the null hypothesis cannot be rejected, so as estimates using the GLS method are consistent as well as efficient, and random effects estimates are chosen. The predicted equation then is the following:

$$\frac{\widehat{X}_{itG}}{X_{itF}} = 0.65 + 1.35 \frac{P_{itG}}{P_{itF}} \quad (5)$$

It can be seen that, as it was expected, the estimations under both models (total relative exports or total relative exports excluding bilateral trade) are very similar. The effect of relative productivity is stronger. With equal productivities, Germany will also be exporting the double than France, but taking exports as a whole, France just need to be almost 4 times more productive than Germany to export the same as them. Of course, this possibility is not realistic, (in the sample, as it can be seen on Table 4-1, on the industry in which France is relatively the most productive relatively it is just 40% more productive than Germany), but it is what the estimated model predicts.

5.1.3 Bilateral Exports

The following step on the analysis is to focus just on bilateral trade. As the Ricardian model only takes into account 2 countries, probably this measure of trade is the most appropriate for analyzing whether the Ricardian theory empirically holds. The results of considering as dependent variable the relative bilateral trade are presented on the table below.

	Fixed Effects	Random Effects
const	-0.0892962 (0.336747)	-0.0513052 (0.340939)
Productivity	1.51608 (0.359214) ***	1.47544 (0.340299) ***

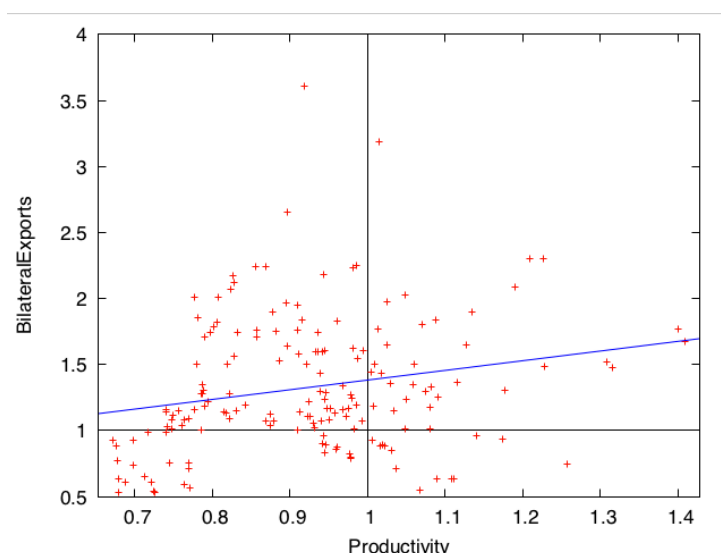
In this case the constant is no longer significantly different from 0. The Hausman test has the highest p-value among all the tests contrasted up to that moment (p-value = 0.715186) so again the random effects estimators appear to be consistent. Thus the estimated model is:

$$\frac{\widehat{B_{itG}}}{B_{itF}} = 1.48 \frac{P_{itG}}{P_{itF}} \quad (6)$$

This implies that with equal productivities, Germany will be exporting 50% more to France than France would export to Germany. But if France becomes 48% more productive than Germany, the exports between them would be equal. This means that if French productivity is the double than Germany's for example, its exports to Germany would be 35% greater than the imports made from it.

In any case, irrespective of the particular measure of trade, it seems that relative productivity has a positive significant relationship with exports.

Figure 5-2. Scatter plot: Bilateral Exports against Productivity



Source: Own elaboration

On Figure 5-2, it can be graphically seen the data employed on the last regression (each point represents an industry on a specific moment on time). The points above the horizontal line of value equal to 1 represent data of industries and moments in which the German exports to France were greater than the French exports to Germany. On the contrary, the points below this line represent data of greater French exports. The same happens with the vertical line (with a value of 1), the points on the right represent moments and industries in which Germany has been more productive than France, while the points on the left represent a higher productivity of France with respect to Germany.

It can be seen on the graph that there is a big concentration of points on the lower part of the graph, around the horizontal line of 1, so the differences on bilateral exports are not very big.

With respect to productivity, it can be seen that the division is not so clear and that there are many points on both sides of the lines (even though there are more in the left).

Note that according to the Ricardian theory, the vast majority of points should be located either on the superior right quadrant or inferior left (understanding quadrant as the division made by the horizontal and vertical lines of value one).

5.2 Exports, productivity and wages

It has been previously mentioned that that it is not as important to have a comparative advantage on productivity but a comparative cost advantage, because actually, what matters is how much it costs to produce (if you need less workers to produce the same amount as the other country, you may have a comparative advantage regarding labor productivity, but if salaries are much higher it is possible that producing in your country becomes more expensive than producing on the other, so you can lose your comparative advantage). On Balassa (1989) relative wages are introduced as another regressor with the aim of isolating the relative productivity effect on the relative exports (from the cost effect).

It is understood as more interesting to capture the comparative cost advantage as a whole since, at the end of the day, trade depends more on relative cost than on relative productivity (even though of course cost depends on productivity). So a model with a regressor that captures both productivity and wages as a whole, not isolating their effects, will be developed.

5.3 Exports and unit labor costs

5.3.1 The variable

This new variable is called Unit Labor Cost and is made of the unit labor cost and wages per employee. It is constructed as follow:

$$Unit\ labour\ cost_{it} = \frac{ULC_{itG}}{ULC_{itF}} = \frac{L_{itG}w_{itG}/Q_{itG}}{L_{itF}w_{itF}/Q_{itF}} \quad (7)$$

Thus, the denominator is made of total cost of production in Germany (wage per employee times number of employees (on industry i and year t) divided by the total production of each industry i on each year t (measured as the current value added of each of them). That way the cost of production per unit of value added is obtained.

As with previous variables, it has been relativized (Germany over France), so if the Unit Labor Cost is greater than 100, it means that it is more expensive to produce one unit of value added on Germany than on France, if it is smaller it implies the opposite.

Table 5-2. Summary cost of Labor

FRANCE =100	Unit Labour Cost
Food beverages and tobacco	132,7
Textiles leather and footwear	112,5
Wood and cork	123,4
Pulp paper printing and publishing	96,7
Chemical rubber plastics and fuel	137,4
Non-metallic products	113,3
Basic metals and fabricated metal products	121,8
Machinery and equipment	113,4
Transport equipment	129,9
Manufacturing n.e.c and recycling	126,2

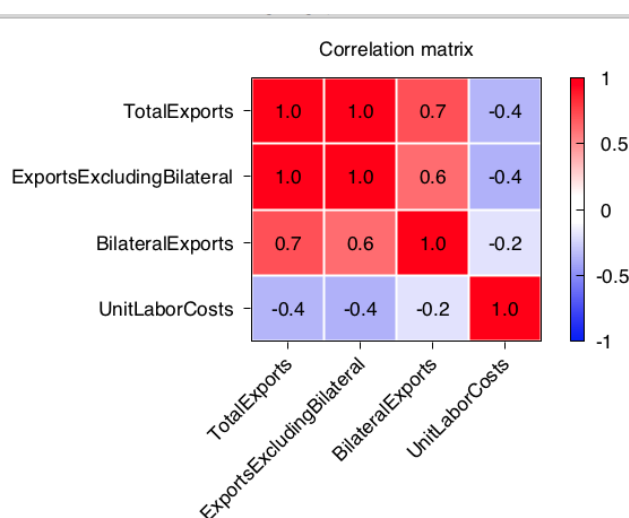
Source: Own elaboration

On Table 5-2, the summary of the Unit Labor Cost by industries can be seen, presented as the average of the 17 years period. It can be seen that the cost of labor is greater on Germany than on France on almost all the industries with the only exception of

Pulp paper printing and publishing industry. This data, according to the Ricardian theory, would imply a greater industrial specialization of France.

Similar to the previous analysis, the correlation matrix has been computed and it is presented below. It can be seen that the strongest correlation of Unit Labor Cost is with Total exports and Total exports excluding bilateral. Correlation between the independent variable (Unit Labor Cost) is negative with the different dependent variables, so to say, if relative ULC increases (if German ULC increases or French one decreases), it is expected that relative exports decrease.

Figure 5-3. Correlation matrix: ULC vs. Exports



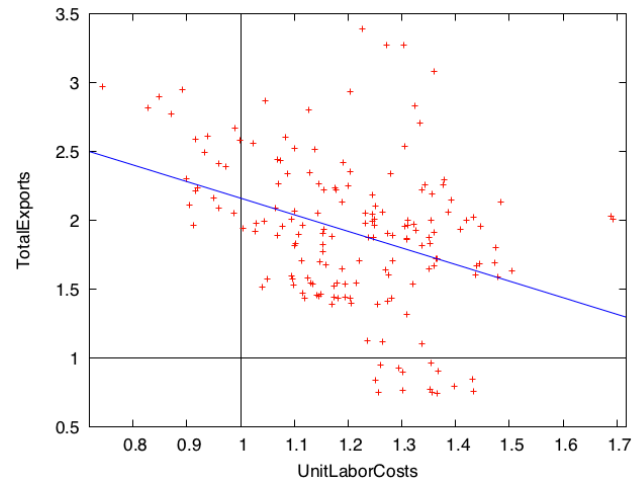
Source: Own elaboration

Next, we will estimate a regression model where total relative exports are used as dependent variable. After that, this variable will be changed by the relative exports with third countries (which means, excluding bilateral trade) and to finish, the variable taken as dependent will be relative bilateral trade.

5.3.2 Total exports

The data has been plotted, representing each point a different observation (one industry in one year). It can be seen that the regressed line is downward slopping representing the negative relationship between the independent and dependent variables.

Figure 5-4. Cost of Production vs. Total Exports



Source: Own elaboration

The vast majority of points are expected to be on the upper left and bottom right quadrants, but the represented data do not appear to satisfy this hypothesis. The reason to expect that, is that the smaller the relative unit labor cost is (meaning that the gap between ULC becomes greater, being French production more expensive), the greater the gap between German exports and French ones would become (relative exports are expected to become greater).

First the following model is estimated:

$$\frac{X_{itG}}{X_{itF}} = \alpha_1 + \beta_1 \frac{ULC_{itG}}{ULC_{itF}} + \varepsilon_{it1} \quad (8)$$

The results for both estimation methods are the following:

	Fixed Effects	Random Effects
const	3.57957 (0.177962) ***	3.57870 (0.235185) ***
Unit Labor Cost	-1.40028 (0.148584) ***	-1.39954 (0.147401) ***

The Hausman test has been constructed and it have a p-value of 0.960179, so there is not have enough evidence to say that GLS estimators are not consistent, so it is assumed that they are and random effects method estimates are chosen since that way they are both efficient and consistent. The resulting estimate is:

$$\frac{\widehat{X_{itG}}}{X_{itF}} = 3.58 - 1.40 \frac{ULC_{itG}}{ULC_{itF}} \quad (9)$$

This equation implies that for equal ULC in Germany and in France, Germany will be exporting more than twice what is going to export France. According to this estimation, being French Unit Labor Cost 50% lower than German one, French exports would overcome German ones, from then on, the higher the cost of Germany with respect to France, the higher the amount of exports of France with respect to Germany will become.

It can be seen on Table 5-2, that on average none of the German industries has a cost that doubles the French one but on the scatter plot of Figure 5-4 can be seen that on some industries, France is exporting more than Germany (all the points below the horizontal line equal to 1).

5.3.3 Total exports excluding bilateral

Now, the dependent variable will be the one originally taken by Balassa (1989), relative exports of Germany over France, but only with third countries.

The results of both regressions are presented on the following table:

	Fixed Effects	Random Effects
const	3.57696 (0.185699) ***	3.58216 (0.248531) ***
Unit Labor Cost	-1.29311 (0.155045) ***	-1.29747 (0.153888) ***

As on the previous regression, the Hausman test is constructed, not rejecting the null hypothesis (p-value= 0.770574) so, again the estimators derived under the random effects method are chosen. On this case, the estimations under both methods are very similar. So the estimated method is as follows:

$$\left(\frac{X_{itG} - B_{itG}}{X_{itF} - B_{itF}} \right) = 3.58 - 1.30 \frac{ULC_{itG}}{ULC_{itF}} \quad (10)$$

If only exports with third countries are taken into account the required ULC gap between Germany and France that would lead to same amounts of exports increases. Now if German Unit Labor Cost is the double than French one, relative exports will equal one, while taking into account total exports it would be 0,78 (France would be exporting 28% more than Germany).

5.3.4 Bilateral trade

Finally, the dependent variable will be bilateral trade. As before, only trade between the countries subject to this study are taken into account. The model that will be estimated is the following:

$$\frac{B_{itG}}{B_{itF}} = \alpha_1 + \beta_1 \frac{ULC_{itG}}{ULC_{itF}} + \varepsilon_{it1} \quad (11)$$

Both fixed effects and random effects methods are applied, the results being:

	Fix Effects	Random Effects
const	3.41640 (0.216838) ***	3.36404 (0.251300) ***
Unit Labor Cost	-1.75233 (0.181043) ***	-1.70840 (0.180042) ***

The Hausman test contrasted has the results presented below:

Hausman test -

Null hypothesis: GLS estimates are consistent

Asymptotic test statistic: Chi-square (1) = 2.81409

with p-value = 0.0934399

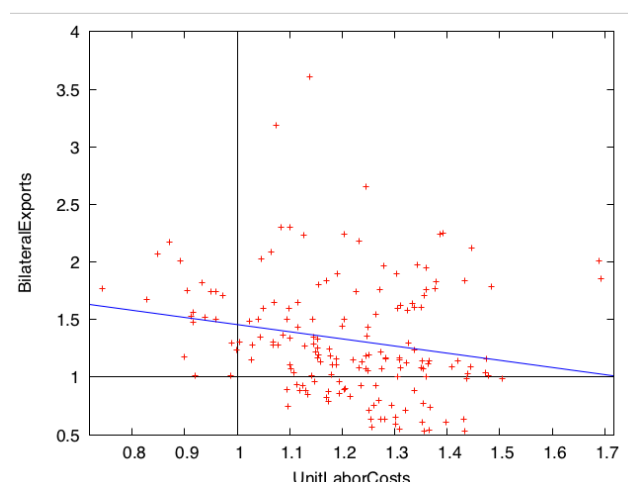
On this the null hypothesis is neither rejected as the significant level is stated at 5%, but if it were stated at 10%, the null hypothesis would have been rejected. So we chose the GLS estimators, the resulting model is:

$$\frac{\widehat{B_{itG}}}{B_{itF}} = 3.36 - 1.71 \frac{ULC_{itG}}{ULC_{itF}} \quad (12)$$

The interpretation of this regression is that for equal unit labor cost on both countries, Germany will be exporting to France 65% more than France to Germany. The way that France has to export more to Germany than to import from them is to reach a production 30% cheaper than the German one. This Unit Labor Cost gap is the smallest of the three regressions, so to say, if France starts to reduce its costs, their exports to Germany (in comparison to the Germans exports to France) will be the first to revert. Then French total exports will become greater than Germans ones and the last to happen will be that exports of France to third countries excluding will exceed Germans ones.

The scatter plot in this case is presented on Figure 5-5.

Figure 5-5. Scatterplot Bilateral Trade vs. Cost of Production



Source: Own elaboration

It can be seen that all the points below the horizontal line of value one are on the right side of the vertical line of value one. This means that on industries where Germany has a relative cost advantage ($ULC < 1$ means that French unit labor cost is higher than the German), Germany exports more than France, what would fit with the Ricardian theory.

6. CONCLUSION

On the present article, a theoretical model has been presented and its performance is tested. For that, a database has been prepared and different models have been estimated for drawing conclusions. The idea was to demonstrate that trade patterns between France and Germany follows the Ricardian model predictions.

The analysis of all estimated regressions, fulfill our initial expectations: the comparative advantage (on productivity and unit labor costs) is a trade driver. In all the cases, the coefficients are significantly different from 0, so it can be said that relative productivity and unit labor cost drive relative exports of the chosen countries (irrespectively of the variable taken to measure them).

The second conclusion is that the relationship among the variables is the expected one: positive for productivity while negative for unit labor costs. This means that the greater the relative productivity is, the greater would become the exports of the more productive country (represented by higher relative exports). The negative relationship between relative unit labor costs and relative exports means that the more expensive is to

produce in one country (relative to the other), the smaller would become the exports of the expensive-production-country relative to the other.

The third conclusion is that the correlation between Exports Excluding Bilateral Trade and both comparative advantage measures is the highest. Total Exports also has a medium correlation with both variables. The smallest correlation is the one of Bilateral Trade measure. There may be other factors explaining Bilateral Trade better than productivity and unit labor costs, such as historical facts, economies of scale, knowledge spillovers... These variables may affect bilateral exports more than total ones, or than exports with third countries because these two countries compared with each other may have large differences, but, when comparing them with other countries of the World, especially if they do not belong to the European Union, these differences between Germany and France can be minimized in comparison with the differences with respect to other countries. These variables are included on the intra-industry trade models, so will probably explain better trade between the analyzed countries, as trade between them is mainly intra-industry.

Finally, after exploring the Ricardian theory in an empirical way, it can be concluded that even if the economic and social framework has radically changed since the Ricardian theory was developed, it continues to explain actual trade patterns. Even if the scenario in which the theory is developed (without transport costs, complete specialization, labor as only input...) was simplified, it can be seen that on a more complex setting, relative productivity continues to be a relative exports driver. In addition, it has been demonstrated that, productivity is not the only source of comparative advantage, but that it also comes from the unit labor costs, which also drives relative exports on the countries.

To conclude, it will be said that even if it is a non-trivial and true concept in theory, it is so empirically. So David Ricardo as he sought, he found a driver of the increase on world wealth that arose from the increase on trade.

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